ELSEVIER

Parkinsonism and Related Disorders 13 (2007) 1–16

Parkinsonism & Related Disorders

www.elsevier.com/locate/parkreldis

Review

Deep brain stimulation in neurologic disorders

Casey Halpern[a,b], Howard Hurtig[a,b,*], Jurg Jaggi[a,b], Murray Grossman[a,b], Michelle Won[a,b], Gordon Baltuch[a,b]

[a]*Department of Neurology, Penn Neurological Institute at Pennsylvania Hospital, Hospital of the University of Pennsylvania, Philadelphia, PA, USA*
[b]*Department of Neurosurgery, Penn Neurological Institute at Pennsylvania Hospital, Hospital of the University of Pennsylvania, Philadelphia, PA, USA*

Received 30 September 2005; received in revised form 14 March 2006; accepted 14 March 2006

Abstract

Deep brain stimulation (DBS) is an effective surgical therapy for well-selected patients with medically intractable Parkinson's disease (PD) and essential tremor (ET). The purpose of this review is to describe the success of DBS in these two disorders and its promising application in dystonia, Tourette Syndrome (TS) and epilepsy. In the last 10 years, numerous short- and intermediate-term outcome studies have demonstrated significant relief to patients with PD and ET. A few long-term follow-up studies have also reported sustained benefits. When successful, DBS greatly reduces most of parkinsonian motor symptoms and drug-induced dyskinesia, and it frequently improves patients' ability to perform activities of daily living with less encumbrance from motor fluctuations. Quality of life is enhanced and many patients are able to significantly reduce the amount of antiparkinsonian medications required to still get good pharmacological benefit. Overall, adverse effects associated with DBS tend to be transient, although device-related and other postoperative complications do occur. DBS should be considered the surgical procedure of choice for patients who meet strict criteria with medically intractable PD, ET and selected cases of dystonia.

Keywords: Deep brain stimulation; Parkinson's; Essential tremor; Dystonia; Tourette syndrome; Epilepsy; Obsessive-compulsive; Depression

Contents

*Corresponding author. Department of Neurology, Penn Neurological Institute at Pennsylvania Hospital, 330 South 9th Street, Philadelphia, PA 19107, USA. Tel.: +1215 829 8407; fax: +1215 829 6606.
E-mail address: hihurtig@pahosp.com (H. Hurtig).

1353-8020/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.parkreldis.2006.03.001

1. Introduction

Stereotactic thalamotomy in the nucleus ventrointermedius of the thalamus (VIM) and pallidotomy of the globus pallidus internus (GPi) were popular neurosurgical treatments for disabling tremor until they fell out of favor with the advent of levodopa therapy in the early 1970s. At its peak, thalamotomy for Parkinson's disease (PD) had limited therapeutic efficacy. Tremor recurred in about 20% of operated cases and serious complications were common. Permanent disability often resulted [1,2]. Bilateral thalamotomy carried an additional high risk of severe impairment of speech [3]. Unilateral pallidotomy is still performed today with conflicting efficacy across studies. Rare long-term studies have shown lack of sustained benefit [4]. Similarly, subthalamotomy has been associated with improvements in contralateral bradykinesia, rigidity and tremor in the short-term [5,6], but decline in benefit has been reported at 6 months, and complete loss of benefit by 18 months [7].

Neurosurgical treatment of parkinsonism was revived in the late 1980s after two decades of experience with levodopa showed a unique set of drug-related complications in advancing PD, including choreiform and dystonic involuntary movements (dyskinesia) and response fluctuations generally referred to as "wearing-off" or "on–off" reactions. At that time, high-frequency stimulation of VIM was used intraoperatively to define the most appropriate target for ablation. Intraoperative observations revealed that stimulation applied prior to thalamotomy completely yet reversibly suppressed tremor. Subsequently, in 1987, Benabid et al. conducted a pilot study of chronic high-frequency stimulation of VIM for tremor suppression without subsequent ablation and were encouraged by the positive results [8]. This led to the first open label clinical trial of high-frequency, electrical deep brain stimulation (DBS) for medically refractory parkinsonian and essential tremor (ET) [9]. The Food and Drug Administration (FDA) approved DBS of the thalamus for parkinsonian and ET in 1997, and in 2002, of STN and GPi for PD. More recently, success in managing these disorders with DBS has opened the door to its use in other neurologic conditions, including dystonia, Tourette Syndrome (TS), and epilepsy.

2. Surgical procedure

DBS consists of stereotactically implanting electrodes through a frontal burr hole into a neural target associated with the basic pathophysiology of the disease [10–15]. During electrode insertion, electrophysiologic recordings identify anatomic boundaries of the target. After implantation of the DBS leads, clinical effects of stimulation in PD and ET are evaluated with the patient awake to assess symptom relief and the threshold of adverse effects prior to closure. Thus, intraoperative electrophysiologic recordings, stimulation and concurrent clinical observation of the patient's signs and symptoms guide implantation for accurate target localization. DBS for primary generalized dystonia (PGD), is commonly performed under general anesthesia, since dystonic postures and involuntary movements of the head and neck can prevent placement of the stereotactic head frame. Moreover, children, who are frequently the victims of dystonia, tend to be less cooperative while awake in the operating room. The effects of stimulation are generally not acutely observable in PGD intraoperatively but emerge over the course of a few weeks postoperatively [16–19].

Once the electrode is in its fixed, correct position, the surgeon inserts the internal pulse generator (IPG) into a subcutaneous pocket adjacent to the clavicle. Although less popular, some experts favor placement of the IPG into the abdominal wall because of faster postoperative healing due to additional thickness of the skin and fatty tissue [20]. The IPG is attached to the DBS lead by a subcutaneously tunneled wire, the top end of which is anchored to the burr hole site at the top of the skull.

Clinical efficacy of DBS depends on accurate, MRI-directed targeting [21]. Pre-targeting using statistical data from atlases [22] provides neurosurgeons with coordinates chosen empirically for their effect on patients' symptoms. Simulation software can identify the electrode's trajectory prior to surgery, avoiding deep sulci, ventricles and superficial large veins if contrast is used.

Perioperative complication rates have been inconsistent with some small studies reporting only device-related complications, while larger series report rates of up to 26% of patients [23,24]. However, most studies note transient adverse effects, such as eyelid-opening